CONCLUSION

It is respectfully requested that the amendments to the Specification and claims be entered. The claims are believed to be in condition for allowance and notice thereof is respectfully solicited. If there are any remaining issues that need to be resolved, it is respectfully requested that a telephone call be placed to the undersigned.

Respectfully submitted,

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AMENDMENT OF THE SPECIFICATION

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate the present invention. In such drawings:

FIG. 1 is a top plan view of a cold plate assembly according to the invention;

FIG. 2 is an enlarged cross-sectional view of the cold plate assembly attached to a printed circuit board shown taken along line 2-2 of FIG. 1;

FIG. 3 is a top plan view of a cold plate assembly using individual heat pipes;

FIG. 4 is an enlarged cross-sectional view of a cold plate assembly attached to a printed circuit board shown taken along line 4-4 of Fig. 3;

FIG. 5 is a cross-sectional view of a cold plate assembly using individual heat pipes attached to a printed circuit board shown taken along line 5-5 of Fig. 3; and

FIG. 6 is a block diagram illustrating steps employed according to one embodiment of the method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The above described drawing figures illustrate the invention in at least one of its preferred embodiments, which is further defined in detail in the following description.

Referring to the figures, a conductive cold plate 25 of the present invention employs an easily manufactured modular construction made of three modules or elements. The three modules including a thermally conductive base 2, a heat pipe assembly 20, and compact heat exchanger 14 are described below.

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A thermally conductive base 2 comprises a rectangular shaped plate of thermally conductive material, and provides a circuit board engagement interface. The interface is formed with a series of recesses that mirror the surface component topology of a circuit board 1, and a standoff 10 for mounting the cold plate 25 to the board 1. This thermally conductive base 2 is preferably made from machined aluminum alloy 6061 T6. In case of mass production to further reduce the cost of this module, die cast aluminum alloy, brass or high conductivity polymer composite can be used.

A heat pipe assembly 20 is preferably constructed as a thermal plane utilizing embedded copper/water heat pipes 9 & 11 sandwiched between two outer aluminum plates. The heat pipes thermal plane utilizes embedded heat pipes to carry the heat from components (the heat source) to the heat sink (heat exchangers) with a typical source to sink temperature difference of 20 degrees centigrade or less. While cooling at both edges is recommended for maximum heat pipe thermal plane performance, single edge cooling is possible with lower performance. Operation is sensitive to orientation of the heat pipes 9, shown in [f]Figure 3 and [f]Figure 4. A heat pipe 9 is a heat transfer device with an extremely high effective thermal conductivity. Heat pipes are evacuated vessels typically circular in cross section which are back filled with a quantity of a working fluid and they are totally passive as used to transfer heat from a source (electronic components) to a sink (heat exchangers) with minimal temperature gradient or to isothermalize a surface. Common heat pipe fluids used are ammonia, water, acetone, and methanol. The heat pipe thermal plane 20, shown in Fig. 1, and heat pipes 9 shown in Fig. 3 are selected depending on the cooling system parameters to carry the heat from the electronic components through the base 2 to the cooling fluid in the heat exchanger 14. When using two compact heat exchangers at the edges of the cold plate base 2, cold plate performance is maximized due to maximum performance of heat pipe thermal plane. Single edge cooling using one heat exchanger is possible with slight de-rated performance. The efficiency of the cold plate [10]25 is dependent on mounting orientation as noted previously.

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With reference to the figures, preferably a heat exchanger 3 and 14 is disposed at one or both opposite ends of heat pipe assembly 20. Preferably, the one or two heat exchangers are either laminated or finned. Moreover, preferably the heat exchanger is made of aluminum or copper and sized to accommodate the heat dissipation capacity of the printed circuit board. The flow rate of flow of the cooling fluid required is determined in proportion to the heat removal capacity of the cold plate [2]25, and a junction temperature range is maintained for the cooled electronic components mounted on the printed circuit board. With reference to Fig. 1, where two heat exchangers are provided, preferably, both are connected together with two aluminum or copper pipes 15 and 16 to transmit the cooling fluid. The pipes are connected to the inlet and outlet of the heat exchangers. The path of the cooling fluid is from an inlet quick disconnect 4 to the lower heat exchanger 3, then to pipe 15 and through the upper heat exchanger 14 to the pipe 16, and finally, out through the quick disconnect [6]5.

Referring to Fig. 2 the three module cold plate base 2, heat pipe thermal plane 20, and heat exchangers 3 and 14 are assembled together using high thermal conductive adhesives or any other thermally conductive bonding technique on the cold plate base outer surface. A template or fixture (not shown) is used to accurately locate the three modules in place relative to the controlling dimensions in the assembly process of the cold plate 25. The circuit board 1,with electronic component item 13, to be cooled is mounted on printed circuit board 1, and gap filler 35 is placed between the circuit board 1 and base plate 2. The circuit boards cooled by the cold plate in this invention are not limited in size, since heat pipe thermal plane or individual heat pipes can be custom designed to accommodate the cold plate size to cool the circuit board electronic components. Also the heat transmission capacity of the heat pipe thermal plane 20 can be customized to maximize the capacity and performance by changing the length, width and thickness of the heat pipe thermal plane 20. With reference to Fig. 3, the working fluid in the heat pipe thermal plane 20 can be of different types and, similarly the individual heat pipes 9, can be of different sizes (diameter, length, etc.) to accommodate the cooling capacity and the

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dimensions of the assembly. In the industry there are standard sizes of heat pipe thermal plane 20 pre-designed and available for production orders. In the case of using a heat pipe thermal plane, the use of the standard size of heat pipe thermal plane reduces the cost of this module in the cold plate of this invention over the use of customized heat pipe thermal planes.

Referring now to Figs. 3 - 5, the cold plate 25 of the present invention, generally employs a highly manufacturable modular construction, including a thermally conductive base, individual heat pipes, and plural heat exchangers. The cold plate 25 includes a rectangular shaped base plate[s] of thermally conductive material such as aluminum, brass or high conductive polymer composite, having a circuit board engagement interface. The interface is formed with a series of recesses that mirror the surface component topology of the circuit board, with thermally conductive gap filler material (not shown). Reference numeral 3 refers to a laminate or finned heat exchanger. Reference numerals 4 and 5 refer to quick disconnects for the cooling fluid entering and exiting the heat exchanger. Reference numeral 7 refers to an electronic component to be cooled. Reference numeral 9 refers to the heat pipes. Reference numeral 2 refers to a thermally conductive base. Reference numeral 12 refers to a gap filler material. Reference numeral 10 refers to an alignment pin.

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With reference to Figs. 3 - 5, in an additional embodiment of the present invention, the three modules of the cold plate assembly are a cold plate base 2, individual heat pipes defining a heat pipe assembly 20, and one or more heat exchangers 3. The three modules are assembled together using brazing material like thermally conductive adhesive or soldering material or any other thermally conductive bonding technique. The individual heat pipes are bonded to the thermally conductive base's outer surface, by providing cavities to house the individual heat pipes. The heat exchanger 3 then is bonded to the cold plate base 2 [in] using thermally conductive bonding material. A template or fixture is used to accurately locate the three modules in place relative to the controlling dimensions in the assembly process of the cold plate.

Referring now to FIG. 6, the structure of the cold plate assembly 25 enables the implantation of relatively straightforward assembly steps. Manufacturing the cold plate begins in step 100, with selecting a thermally conductive plate to define the base. Either casting or machining the profile of the topology on the far side forms the base. Then selecting the heat pipe thermal plane or individual heat pipes at step 102. Selecting the compact heat exchanger with the pipes in step 104.

Once the three main modules are selected, bonding them together as shown in Figs. 1 - 5 makes the assembly of the cold plate step 106. Using a thin layer of high thermal conductive adhesive makes the bond. While the inventor has determine bonding using high thermally conductive adhesive offers the preferred results, other known processes may be employed without damaging the heat pipe thermal plane or the individual heat pipes.

Assembling the cold plate includes the base, the heat pipe thermal plane or individual heat pipes and the heat exchangers. The thermal capacity of transmitting the heat as

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AMENDMENT OF THE CLAIMS

Please amend Claims 13, 14, 16 - 18 as follows:

13. (Once amended) A cold plate assembly for cooling a circuit board assembly, said cold plate assembly comprising:

a heat pipe assembly including at least one heat pipe adapted for internally circulating a first thermally conductive fluid for carrying heat dissipated from electrical components of a circuit board; and

at least one compact heat exchanger [affixed] engaging and thermally connected to said heat pipe assembly, said heat exchanger adapted for internally circulating a second thermally conductive fluid and for carrying heat dissipated from said heat pipe assembly.

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14. (Once amended) The cold plate assembly for cooling a circuit board assembly of claim 13, said cold plate assembly further comprising:

a thermally conductive base engaging said heat pipe assembly for being affixed to a circuit board, said thermally conductive base including a plurality of recesses sized and configured for receipt of electrical components on a circuit board.

15. The cold plate assembly for cooling a circuit board assembly of claim 13, wherein said compact heat exchanger includes an inlet for receiving said second thermally conductive fluid and an outlet for emitting said second thermally conductive fluid.

16. (Once amended) The cold plate assembly for cooling a circuit board assembly of claim 13 wherein said heat pipe assembly is constructed as a thermal plane including at least one [or more] internal heat pipe[s].

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17. (Once amended) A cold plate assembly for cooling a circuit board assembly, said cold plate assembly comprising:

a thermally conductive base for being affixed to a circuit board, said thermally conductive base including a plurality of recesses sized and configured for receipt of electrical components on a circuit board;

a heat pipe assembly engaging and thermally connected to said thermally conductive base, said heat pipe assembly constructed as a thermal plane including one or more internal heat pipes, said one or more heat pipes for internally circulating a first thermally conductive fluid for carrying heat dissipated from electrical components of a circuit board; and

at least one compact heat exchanger [affixed] engaging and thermally connected to said heat pipe assembly, said heat exchanger adapted for internally circulating a second thermally conductive fluid and for carrying heat dissipated from said heat pipe assembly, said compact heat exchanger including an inlet for receiving said second thermally conductive fluid and an outlet for emitting said second thermally conductive fluid.[.]

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18. (Once amended) A circuit board and cold plate assembly comprising:

a circuit board assembly including electronic components mounted thereon;

a heat pipe assembly thermally connected to said electronic components, said heat pipe assembly including at least one heat pipe adapted for internally circulating a first thermally conductive fluid for carrying heat being dissipated from said electrical components; and

at least one compact heat exchanger engaging and thermally connected to said heat pipe assembly, said heat exchanger adapted for internally circulating a second thermally conductive fluid and for carrying heat dissipated from said heat pipe assembly.

19. The circuit board and cold plate assembly of claim 18 further comprising a thermally conductive base affixed to said circuit board, said thermally conductive base provided to transfer heat from said electronic components to said heat pipe assembly.

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20. (Once amended) The circuit board and cold plate assembly of claim 18 wherein said heat pipe assembly is constructed as a thermal plane including at least one [or more] internal heat pipe[s].

21. The circuit board and cold plate assembly of claim 18 wherein said compact heat exchanger includes an inlet for receiving said second thermally conductive fluid and an outlet for emitting said second thermally conductive fluid.

22. (Once amended) The circuit board and cold plate assembly of claim [18] 21 wherein said heat pipe assembly is constructed as a thermal plane including at least one [or more] internal heat pipe[s].

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